Optimal algal cultivation for used water resource recovery

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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

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1. INTRODUCTION

Current resource recovery strategies [1]:
- Metal salt addition for phosphorus precipitation
- Ultrafiltration

Disadvantages:
- High energy demand
- Requires the use of chemicals

Resource recovery through a two-stage bacterial-algal system [2]:
- Enhanced biological phosphorus removal and recovery system (EBP2R) to produce green microalgal growth medium with optimised N-to-P ratios
- Optimal algal cultivation, thereby intracellularly storing N and P
- Direct application on land for fertigation

Advantages:
- Completely biochemical process
- Comparably lower environmental impacts

Effluent criteria → Optimal N-to-P ratio for algal growth

Effluent criteria → Very Low dissolved $NH_{3,4}^{+}$ and PO_4^{3+}

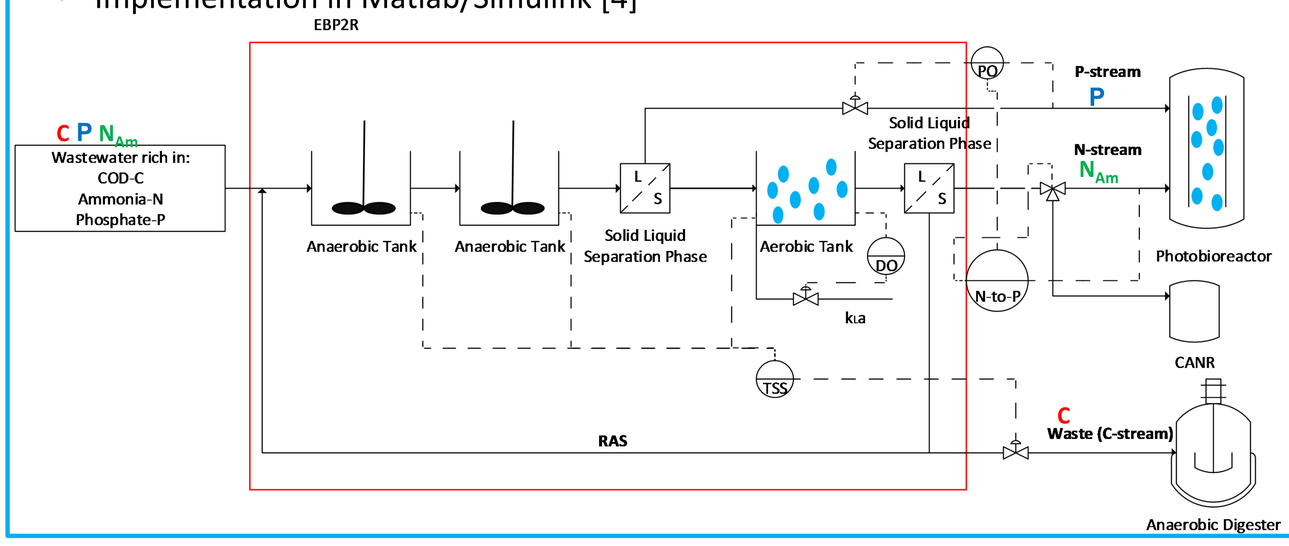
Fertigation

Objective: How to effectively maintain optimal N-to-P ratio in the EBP2R effluent which is the influent of the photobioreactor?

2. METHODS

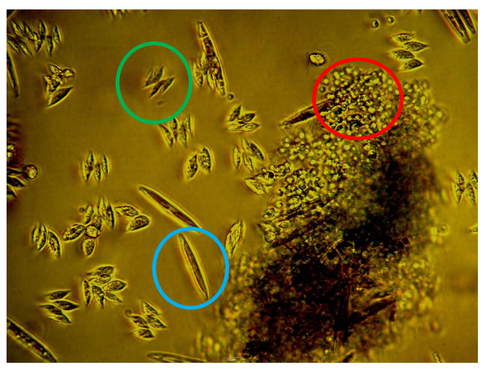
EBP2R-MODELLING

EBP2R performance assessed via **dynamic simulations**:
- Activated sludge model ASM-2d [3]
- Implementation in Matlab/Simulink [4]



PBR-EXPERIMENTS

Photobioreactor performance assessed in **lab-scale** reactors:
- 1.4 L reactors treating the effluent of an EBPR
- **Microbial diversity** analysis and quantification via novel image analysis tool: **shape recognition**



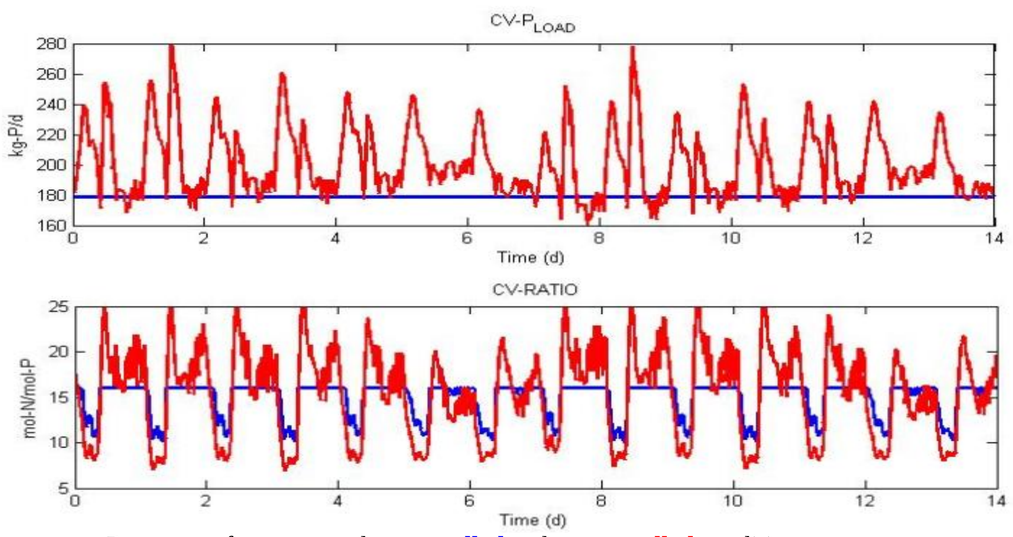
- *Chlorella sp.*
- *Scenedesmus sp.*
- *Diatoms*

3. RESULTS

EBP2R Performance:

System response to step disturbances in the influent:
- Total nitrogen (± 30%) : the control system rejects the influent disturbance.
- Total COD (± 20%) : the control system rejects the influent disturbance.
- Total phosphorus (± 20%): the control system rejects an increase of phosphorus load into the system; the control system fails keeping the optimal phosphorus load when influent load decreases due to process constraints.

System response to dynamic influent conditions :
- Control system maintains stable phosphorus load
- Control system fails to keep the optimal N-to-P ratio when the nitrogen influent load is low

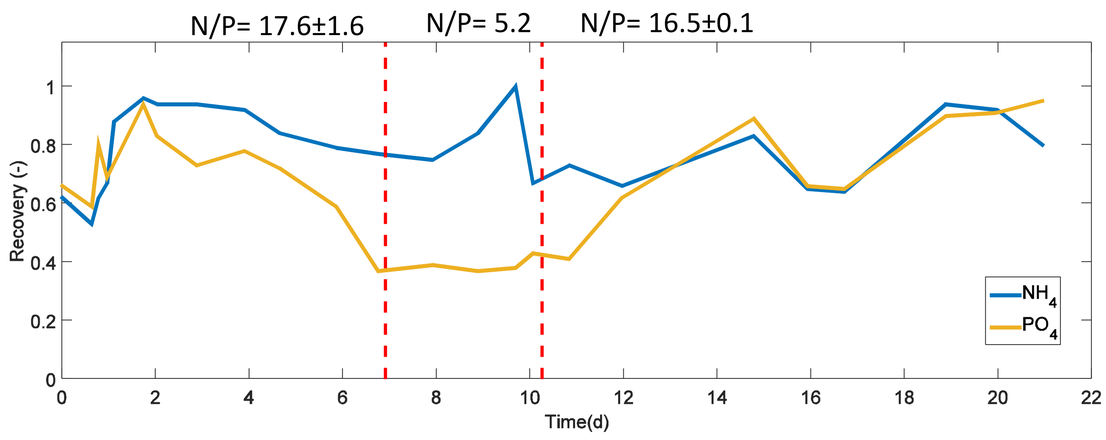


Process performance under **controlled** and **uncontrolled** conditions

Photobioreactor Performance:

N-to-P ratio of 17 (optimal):
- Effective nutrient removal and storage:
  - Up to 95% nitrogen removal
  - Up to 85% phosphorus removal
- Stable microbial community: *Chlorella sp.* (10%) and *Scenedesmus sp.* (90%)

N-to-P ratio of 5 (suboptimal):
- Poor phosphorus removal (40%)
- Culture contamination by *Diatoms* (34%) present in the influent



4. CONCLUSIONS

- **EBP2R effluent N-to-P** ratio shows **limited variability** under controlled conditions
- **EBP2R** can **support optimal algal growth**
- The proposed **control structure** has the potential to be implemented at **large scale**
- **N-to-P** ratio is a powerful tool for **microbial community control** in open PBR

ACKNOWLEDGEMENT

The research was financially supported by the **Integrated Water Technology** (InWaTech) project, a collaboration between the Technical University of Denmark (DTU) and the Korea Advanced Institute of Science and Technology (KAIST) and by the European Commission (**E4WATER Project**, FP7-NMP-2011.3.4-1 grant agreement 280756)

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